19th ICCRTS

Regional Value Analysis at Threat Evaluation

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Abstract

It is necessary to make threat evaluation effectively in order to assign weapon at air defense management. The threat analysis which is made for defending assets more than one or a region and for only one asset is different. Also in classical threat analysis in case of both threats' parameters being the same, the priority is the same. In the threat evaluation importance of asset is ignored. When the importance of the asset is determined, it is necessary to determine the threat's target to identify threat's priority. Although it is possible to perform the target detection massive information is needed as there are too many parameters and variables. Difficulties and possibilities of providing this information makes it impossible to be more realistic target identification. Also the reliability of the model in which the threat's target detected decreases. Consequently, target detection is needed rather than any other consideration. Literature study on threat evaluation is made, there is not a similar study found in the literature and a new model is put forth to eliminate the deficiency identified in this study. Studied model is not a different threat evaluation method. The model is done to perform more effective regional air defense threat evaluation. Regional value will provide input as a parameter in any desired models.

At the first stage of model, the importance degrees of targets are identified. Then regional value analysis is made according to importance of assets. As a result of analysis a regional value map is generated. The region value is given according to threat's grid. Thus, the threats having the same parameters are provided priority according to the value of their region's value. The threat evaluation made for weapon assignment is done more accurate and the possible damage is minimized.

1. Introduction

Due to economic problems and NATO's reconstruction various countries in NATO are decreasing as the quantity of the armed forces. Despite the decrease in quantity of forces, to pursue activities to increase qualifications are in need. In this case, a smaller rapid and deployable force structure comes to the fore. To achieve this it is necessary to create a technology-intensive force structure. NATO aims to do effective duty with the technology of network-enabled capability. With network enabled capability (NEC) information received from sensors fusion is performed, decision-makers are supported to decide and transmitting the decision to the corresponding weapon system is provided.

Shared joint air picture with the NEC increases situational awareness in air defense sensors and weapons obliged to be at the same place are eliminated. Cruise missiles can be transferred from one system to another during the cruise phase. Moreover, the target can be changed after missiles release. Range, effectiveness and stroke percentage are increasing with NEC. Stroke moment can be displayed with the help of the missile's ability of visual data stream. So, the attacks can be assessed instantaneously. Capabilities of sensors and weapon systems are not efficient only by themselves. One of the important stages is forming usable information by fusion of data. Threat evaluation is one of the processes that is used in the information obtained by air defense management. The aim of threat evaluation is determining priority of threats and attacking the suitable threat.

Air force can attack the targets in a short time thanks to the ability to speed, range, and strategic attack capabilities. Thus, air defense of the country which will be protected from attack is required to made decision and react as soon as possible. The assignment of the right weapon to the right threat in a short time is vital. The process, critical for Countries' air defense,

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14. ABSTRACT

It is necessary to make threat evaluation effectively in order to assign weapon at air defense management. The threat analysis which is made for defending assets more than one or a region and for only one asset is different. Also in classical threat analysis in case of both threats? parameters being the same, the priority is the same. In the threat evaluation importance of asset is ignored. When the importance of the asset is determined, it is necessary to determine the threat?s target to identify threat?s priority. Although it is possible to perform the target detection massive information is needed as there are too many parameters and variables. Difficulties and possibilities of providing this information makes it impossible to be more realistic target identification. Also the reliability of the model in which the threat?s target detected decreases. Consequently, target detection is needed rather than any other consideration. Literature study on threat evaluation is made, there is not a similar study found in the literature and a new model is put forth to eliminate the deficiency identified in this study. Studied model is not a different threat evaluation method. The model is done to perform more effective regional air defense threat evaluation. Regional value will provide input as a parameter in any desired models. At the first stage of model, the importance degrees of targets are identified. Then regional value analysis is made according to importance of assets. As a result of analysis a regional value map is generated. The region value is given according to threat?s grid. Thus, the threats having the same parameters are provided priority according to the value of their region?s value. The threat evaluation made for weapon assignment is done more accurate and the possible damage is minimized.

15. SUBJECT TERMS

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was studied in compliance with today's understanding of operation. A new model has been demonstrated to determine the threat which is the "Optimal threat" for being destroyed. A general threat evaluation is mentioned in the second part of the study. How the threat evaluation can be done more effectively with the regional value analysis will be covered in the third part of the study. Fourth and fifth part of the study contain the evaluation and the result.

2. Threat Evaluation

According to Merriam Webster, threat is an expression of intention to inflict evil, injury, or damage [1]. As for air defense, threat is an aircraft, cruise missile or ballistic missile that aims to destroy, to defuse or to harm the functions of the targets. Threat evaluation is a process of prioritization and determination the enemy tracks with some specific methods.

For the success of the air defense, there are five command and control functions. These are target detection, target tracking, target identification and classification, threat evaluation and weapon assignment [2]. These functions are executed in order. Radar operators detect tracks at track production area. Detected tracks are traced and tried to be identified. Identification is done by electronic and procedural methods. If the track is identified as enemy, weapon assignment is the following step. If there are a great number of tracks identified as enemy, then each threat's value is calculated and prioritized. Weapon assignment is done for this priority.

Various decision support models for threat evaluation have been developed in the literature. Bayesian networks [3], [4], [5] and fuzzy logic [6], [7] models come to the fore. Also various parameters were used in the models. However in Liebhaber and Feher's threat evaluation study, the 18 parameters [4] they determined were generally accepted. In the threat evaluation made with the Bayesian network approach Johansson divided these parameters into three groups like proximity, capability and intent. Parameters determined by Johansson are shown in Table 1. These parameters are often used to calculate priority value of the threat of target [8]. Irandust and others have made a similar grouping by using opportunities parameters rather than their intentions parameters in decision support software they prepared [9].

Group	Parameters
Proximity Parameters	Range from Closest Point of Approach (CPA), Time to CPA, CPA in Units of Time, Time Before Hit and Distance
Capability Parameters	Target Type, Weapon Type, Fuel Capacity, Maximum Radius of Operation
Intent Parameters	Target's Kinematics, Number of Recent Maneuvers

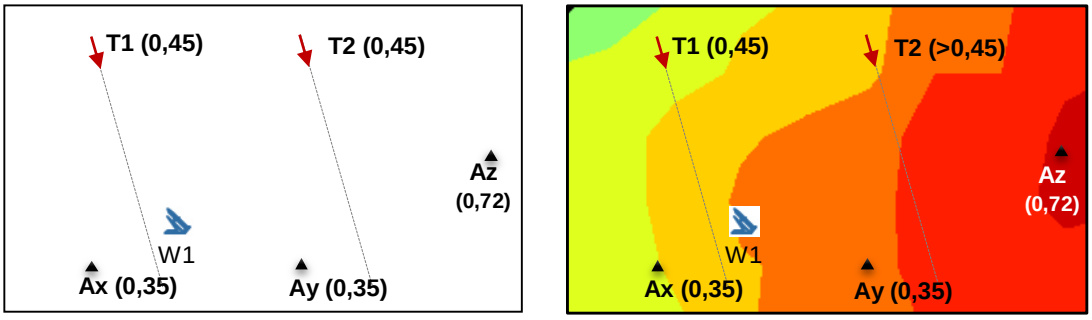
Table 1 The Classification of Johannson's Threat Evaluation Parameters

In this study, the parameters like altitude, heading, speed, regional value, type of aircraft value and role of aircraft value are used for threat evaluation. Evaluation of type of aircraft value is calculated by night flight, air refueling and link capability, altitude and speed limits, G capacity and operation radius. Type of aircraft value shows similarity with Johansson's ability parameters. But in regional threat evaluation, to detect the possible target is not very easy, so region value is used instead of Johansson's proximity parameters. Giving value to threat is done according to region of threat. Thus, the effect of the threat's unpredictable behavior will be minimized. However in the air force planning, it was needed to be planned more than one aircraft to a target until the end of the 20th century. However, as a result of the developments in precision missile aircraft gained capability to attack more than one target [10]. Therefore, thinking like threats will attack a single target will result in misjudgment.

3. Regional Value Analysis (RVA)

The purpose of the regional value analysis (RVA) is to reveal a threat evaluation model more suited to the new operational concept, is to gain a new perspective to threat evaluation. Evaluating threats according to the targets' priority and distance is aimed.

3.1. Why RVA

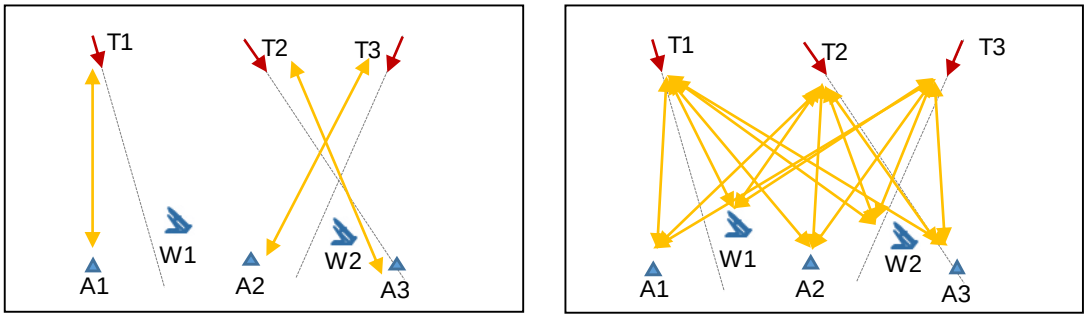


(a) (b)

Figure 1 Regional Value Analysis at Threat Evaluation

Threat evaluations are usually made towards one asset's air defense. These studies are developed and threat evaluations are upgraded to regional air defense. But, according to those studies threat priorities are considered equal, if the threat parameters are similar or the same. As shown on Figure 1 (a) if the speed, altitude, heading, payload and probable target for both T1 and T2 are the same, according to classical threat evaluation threat value for both T1 and T2 will be equal. But if threat is evaluated according to the regional value analysis as shown on Figure 1 (b), threat value for T2 will be greater than T1. Although they have the same parameters, T1 is in the yellow area and T2 is in the orange area. The reason for this difference is that T2 is closer to A_z asset. Although A_y is seen as T2's target in Figure 1 (a and b), it may suddenly switch to A_z. A_z which is more valuable target than A_x and A_y in this example. Also in this era on threat may attack to several assets. It is probable that after attacking A_y, T2 will attack to A_z. Consequently, in case of attacking to several elements, threat evaluation will be made more accurate with regional value analysis. Besides the effects of unpredictable maneuvers of the threat will be eliminated.

Targets' importance is taken into consideration for some studies in which weapons assignment is made. But for the evaluation of regional value analysis, the effects of all targets' importance are evaluated regionally. In Bin's dynamic weapon assignment, every threat's value according to every target was used. The objective function aims to minimize threat's survival possibility [11]. But the state of being threats according to only the selected target was included in the calculation. However the inability to predict the target which the threat heads and calculating according to only headed target reduces the efficiency of the calculation.



(a) (b)

Figure 2 Comparation of Weapon Assignment and RVA

In the weapon assignment study made by Bin, values of the targets that are expected to be attacked are used as shown at Figure 2 (a) in the weapon assignment. In RVA, all the targets' values are used for all the threats' value calculation as seen at Figure 2 (b). Thus weapons assignment will be more effective with regional value analysis.

3.2. Formulation

Sets and variables for RVA are shown as:

A : Set of Assets,

N : Set of Points,

a_j : Target value, $j \in A$,

b_{nj} : Point value,

u_n : Updated point value,

r_{nj} : Distance between target and point,

Rw : Most effective air to surface missile range,

$$b_{nj} = \begin{cases} a_j & if\ r_{nj} \leq Rw, \\ 0 & if\ r_{nj} > Rw, \end{cases} \quad (1) \qquad u_n = \frac{\sum_{j=1}^{|A|} b_{nj}}{\max_n b_{nj}} \quad \forall j \in A, \forall n \in N \quad (2)$$

In regional value calculation Rw is used as the range of the longest-range air to surface missile enemy country has. In formula 1 it uses target's value (b_{nj}) to the all points within Rw distance. In formula 2, there is the sum of all the targets' value for each points. Then current point values are calculated by divided by the highest one of all point values and converting values to the 0-1 range.

3.3. Calculation of RVA

RVA calculation is done according to target's value. The first step at calculation RVA is calculating values of targets. Within the Scenario 66 targets including strategic, operative and tactical level have been generated consisting bases, radars, Surface to Air Missile (SAM) batteries and command and control centers. Target values are calculated according to importance, physical condition and protection of the capacity. The results of calculation are shown at Table 2.

Target	Value	Target	Value	Target	Value
A1	0,765	**A23**	0,465	**A45**	0,349
A2	0,674	**A24**	0,462	**A46**	0,348
A3	0,664	**A25**	0,458	**A47**	0,345
A4	0,652	**A26**	0,458	**A48**	0,344
A5	0,605	**A27**	0,452	**A49**	0,34
A6	0,591	**A28**	0,451	**A50**	0,339
A7	0,589	**A29**	0,451	**A51**	0,336
A8	0,527	**A30**	0,449	**A52**	0,331
A9	0,49	**A31**	0,44	**A53**	0,33
A10	0,486	**A32**	0,432	**A54**	0,323
A11	0,483	**A33**	0,375	**A55**	0,321
A12	0,48	**A34**	0,362	**A56**	0,313
A13	0,478	**A35**	0,362	**A57**	0,312
A14	0,478	**A36**	0,362	**A58**	0,31

A15	0,478	**A37**	0,361	**A59**	0,31
A16	0,477	**A38**	0,36	**A60**	0,309
A17	0,476	**A39**	0,359	**A61**	0,306
A18	0,474	**A40**	0,359	**A62**	0,303
A19	0,472	**A41**	0,357	**A63**	0,295
A20	0,47	**A42**	0,357	**A64**	0,291
A21	0,468	**A43**	0,354	**A65**	0,29
A22	0,465	**A44**	0,349	**A66**	0,269

Table 2 Target's Values

RVA study is shown on the map in order to increase situational awareness. Regional value map which has been generated by assuming the enemies' the most effective air to surface weapon as 50 nautical miles is shown in Figure 3.

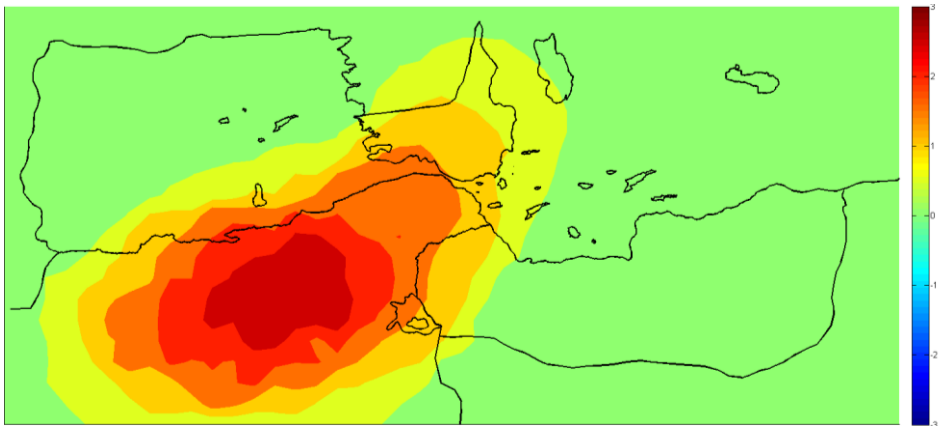


Figure 3 Map of RVA

To be shown on the map totally 924 point is determined including 44 units in latitude and 21 units in longitude at intervals of 0.5 degrees. The determined points are shown at the Figure 4.

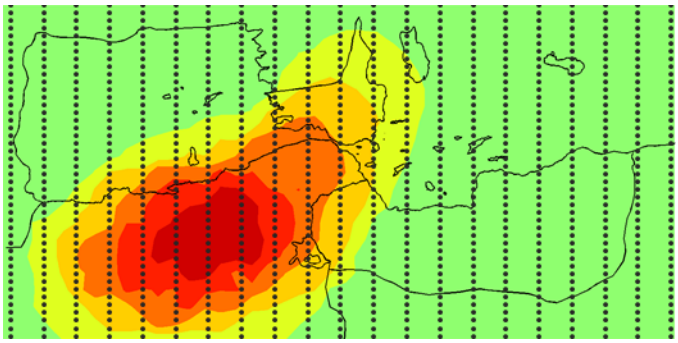


Figure 4 Points used in RVA

4. Discussion

In proximity parameters which is used in threat evaluation there are parameters such as distance and time. Proximity parameters require evaluating according to a point or a target. The probability of determining which threat is heading which target is low. Deception of the enemy must be considered. In this case, instead of making threat evaluation according to one target, making it according to the values determined regionally would be more appropriate. The points shown in Figure 4 constitute its own grid's a bottom right coordinates. Updated point value expresses grid's value. Threat's value in the grid is used as regional value in threat

evaluation. It can be used in threat evaluation such as altitude, speed, heading, type of aircraft, etc.

By reducing the interval values used to identify points, the sensitivity of calculation can be more accurate. Also, if the threat's missiles are known, effective weapon range can be accepted as range of the longest-range air to surface missile.

5. Conclusion

Studies in the literature have been done mainly to evaluate threats which are headed to a single element or a group of elements. The difficulty to determine which threat heads which target and to estimate enemies' course of action in threat evaluation for a regional air defense emerges as a problem. As a solution to these problems, the study of regional value analysis is done. So, threats' evaluation is provided according to its position or heading coordinate. Also, if the threat plans to attack more than one target there will not be atony at evaluation as it is made according to targets. Eventually making threat evaluation regionally will be more effective and accurate. A more effective threat evaluation helps make an effective weapon assignment and this provides a more effective air defense. This will minimize the probability of having damage from the targets which the enemy plans to attack and perhaps it will change the fate of war.

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Regional Value Analysis at Threat Evaluation

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Agenda

- Overview of Air Defense
- Threat Evaluation & Weapon Assignment
- Problem
- Regional Value Analysis
- Formulation
- Conclusion

Overview of Air Defense

- Detection
- Identify
- Intercept
- Destroy

Threat Evaluation & Weapon Assignment

Threat Evaluation

As for air defense, threat is an aircraft, cruise missile or ballistic missile that aims to destroy, to defuse or to harm the functions of the targets. Threat evaluation is a process of prioritization and determination the enemy tracks with some specific methods.

Various decision support models for threat evaluation have been developed

Bayesian networks and fuzzy logic models come to the fore.

Weapon Assingment

Weapon assignment consists of finding an optimal assignment of a set of weapons of various types to a set of targets in order to maximize the total expected damage done to the opponent.

$$\prod_{k}^{T}\left(1-\omega_{jk}\prod_{i}^{M}(1-P_{ik})^{X_{ik}}\right)$$

ω_{jk} – Threat`s priority

X_{ik} – represents the assignment of as many weapons

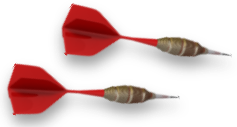
P_{ik} – probability of kill

Threat Evaluation

Liebhaber has identified 6 basic totally 18 parameters for threat evaluation.

Liebhaber & Feher

Basic	origin, IFF mode, intel, air route, altitude, radar and electronic
Other	airline, coordinated activity, speed, closest point of approach (CPA), feet wet/dry, maneuvers, number/composition, own support, range/distance, visibility, weapon envelope, wings clean/dirty



Threat Evaluation

Johansson divided same parameters into three groups

Johansson

Group	Parameters
Proximity Parameters	Range from Closest Point of Approach (CPA), Time to CPA, CPA in Units of Time, Time Before Hit and Distance
Capability Parameters	Target Type, Weapon Type, Fuel Capacity, Maximum Radius of Operation
Intent Parameters	Target's Kinematics, Number of Recent Maneuvers

Problem

Liebhaber & Feher

Basic	origin, IFF mode, intel, air route, altitude, radar and electronic
Other	airline, coordinated activity, speed, closest point of approach (CPA), feet wet/dry, maneuvers, number/composition, own support, range/distance, visibility, weapon envelope, wings clean/dirty

Johansson

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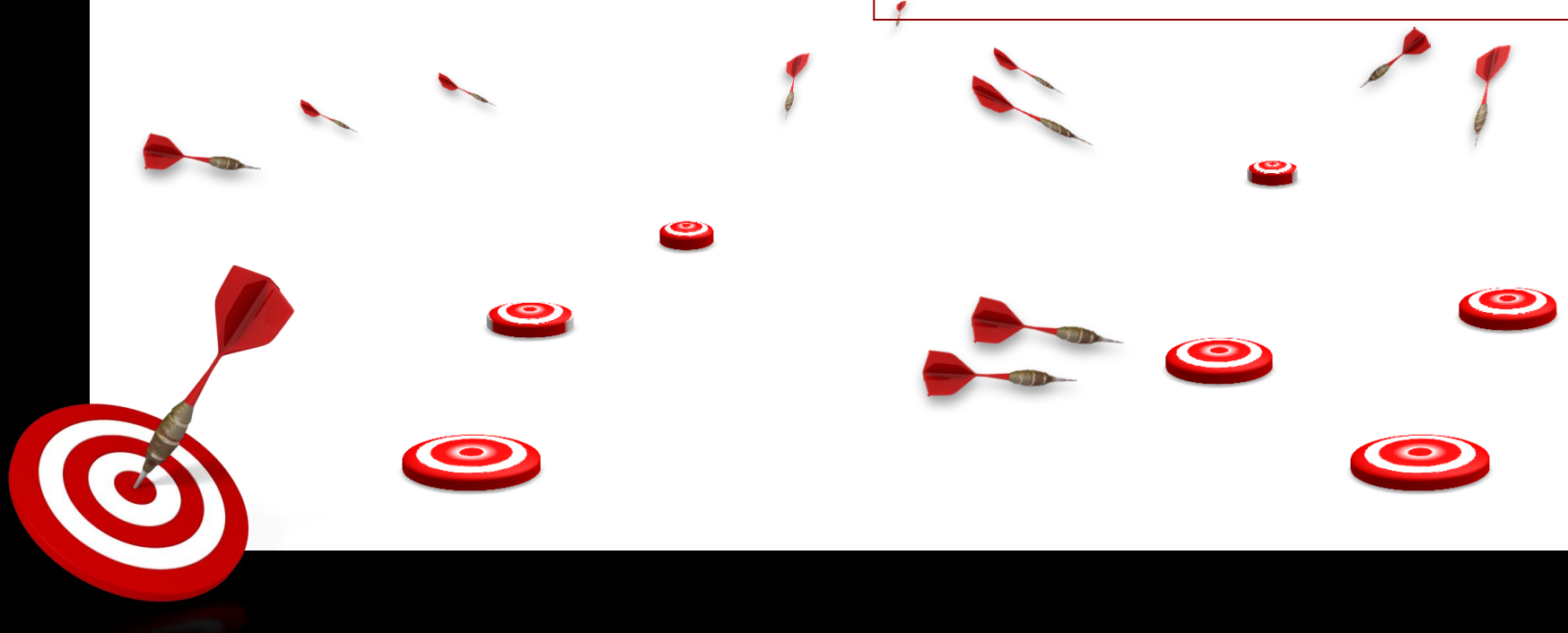
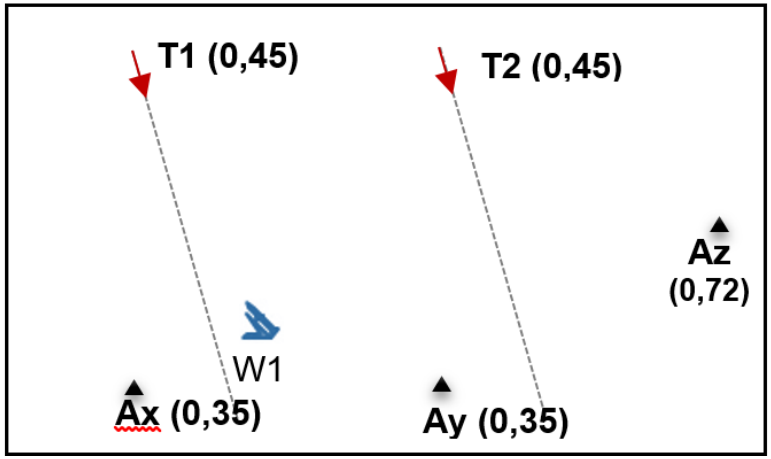
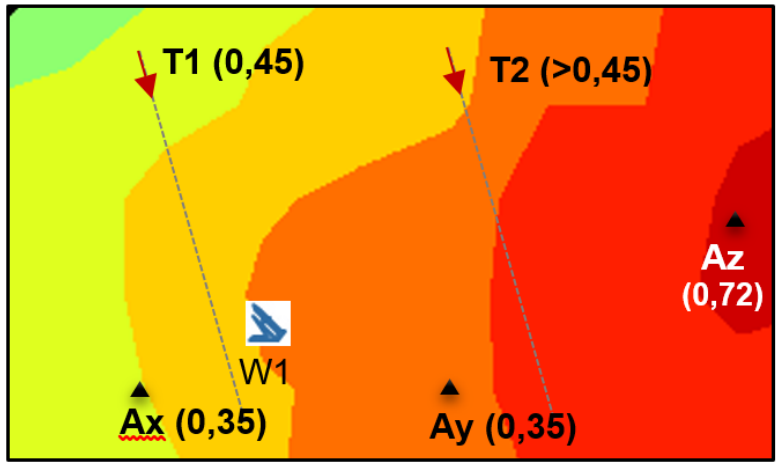


Regional Value Analysis

Classic Threat Evaluation



With Regional Value Analysis



Formulation (Target Values)

Set and Variables

A : Set of Assets,

a_j : Asset value, $j \in A$,

T_j : Asset priority

V_j : Vulnerability

R_j : Repairing capability

Alt_j : Alternate

D_j : Distribution

Rng_j : Range to threat

Lc_j : Land condition

Dl_j : Diagnosis Level

$Rdrc_j$: Radar coverage

$SAMc_j$: SAM coverage

$RngB_j$: Range to border

Formulas

$$a_j = T_j + V_j + R_j + Alt_j + D_j + Rng_j + Lc_j + Dl_j + Rdrc_j + SAMc_j + RngB_j$$

Formulation

Set and Variables

A : Set of Assets,

N : Set of Points,

a_j : Target value, $j \in A$,

b_{nj} : Point value,

u_n : Updated point value,

r_{nj} : Distance between target and point,

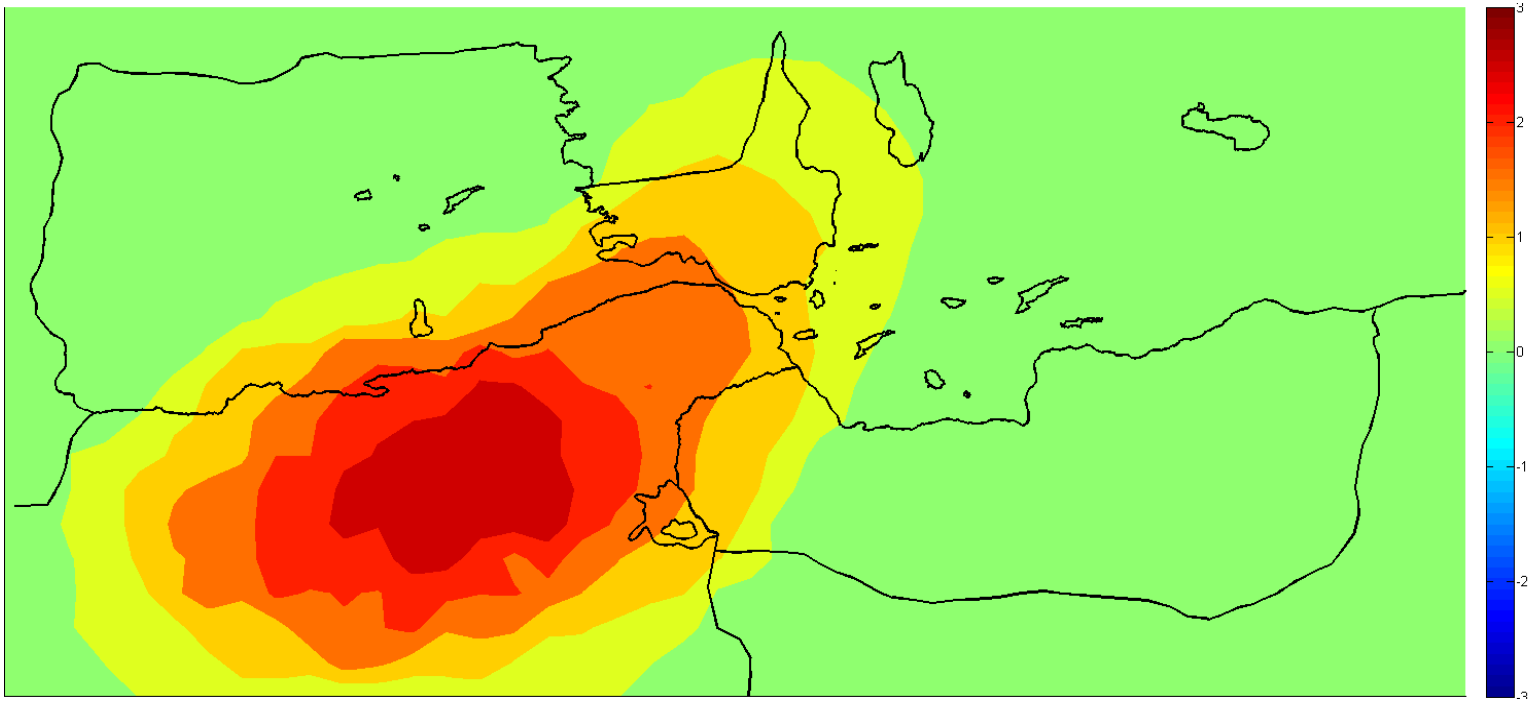
Rw : Most effective air to surface missile range,

Formulas

$$b_{nj} = \begin{cases} a_j & if\ r_{nj} \leq Rw, \\ 0 & if\ r_{nj} > Rw, \end{cases} \quad (1)$$

$$u_n = \frac{\sum_{j=1}^{|A|} b_{nj}}{\max_n b_{nj}} \quad \forall j \in A, \forall n \in N \quad (2)$$

Regional Value Map



Within the Scenario 66 targets including strategic, operative and tactical level have been generated consisting bases, radars, Surface to Air Missile (SAM) batteries and command and control centers.

Conclusion

- Regional Defense
- Minimize Unpredictability
- Efficiency
- Accuracy

QUESTıONS

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